Cosmic Times: 1929

Cosmic Times is a series of six posters with classroom lessons that trace the development of our understanding of the nature of the universe during the past century.

This poster is the second edition of the *Cosmic Times*, and the articles in this edition build on the concepts introduced in the 1919 edition. The headline story is that Edwin Hubble has discovered that the Universe is expanding. The idea of an expanding Universe is contrary to Einstein's assumption of a static Universe, and while Einstein was not convinced of the veracity of Hubble's results, the astronomical community generally accepted them. This discovery was built on a second important discovery that the Milky Way is one of many galaxies in the Universe. This settled a debate among astronomers, which Harlow Shapley and Heber Curtis had expounded upon in a formal debate in 1920. This edition also contains brief biographies of Edwin Hubble and his assistant Milton Humason.

The language in the 1929 newspaper mimics the style of writing that would have appeared in a real 1929 newspaper. Like 1919, the language and sentence structure of this edition are more difficult than modern newspapers. The poster mimics the newspapers of the time, however, we have taken some creative license to make it more readable in a classroom setting. Real newspapers of the time would have had 5-7 narrow columns of small type.

The *Cosmic Times* website, http://cosmictimes.gsfc.nasa.gov/, provides a complete teacher guide for this poster and the accompanying lessons. There you can also find two newsletter versions of the poster: one of the newsletters contains the same text as the poster, while the other translates the text to a slightly lower reading level. The web site also includes a glossary. We provide here a summary of the articles, a synopsis of the lessons, and two of the lessons.

Summary of the Articles

(for more information, see
http://cosmictimes.gsfc.nasa.gov/1929/guide/teachers_guide.html)

Andromeda Nebula Lies Outside Milky Way Galaxy

Up until the early 1920's, astronomers did not have definitive proof that galaxies existed outside our Milky Way Galaxy. It was through the use of Cepheid variable stars and the 100-inch telescope at Mt. Wilson that Edwin Hubble determined the distance to Andromeda, and found it to be outside our own Galaxy.

Universe is Expanding

This article describes Edwin Hubble's discovery of that the universe is expanding. Hubble put together his distances to the spiral nebulae with the redshifts measured in their spectra. The linear relationship between these two quantities showed that the Universe is expanding.

"Great Debate" Resolved

Hubble's measurement of the distance to the Andromeda Nebula settled a debate that had long raged among astronomers. This article reviews both sides of this issue that were brought to light in a debate staged between Harlow Shapley and Heber Curtis in April 1920.

The Minds atop Mount Wilson

The story of science is as much about the scientists involved as it is about the science itself. These two brief biographies highlight the different lives of two of the astronomers who shaped our understanding of the Universe in the early 20th century.

Classifying Nebulae

The first step to understanding many different phenomena can often be to classify them. To this end, Hubble looked at a large sample of galaxy images and classified them according to their features. The general classifications he used were: spiral, elliptical and irregular.

In Their Own Words

This quote from Edwin Hubble is from an article in the Fresno Bee, which appeared Oct 23, 1927, and offers his own perspective on his discoveries.

Summary of 1929 Cosmic Times Lessons

Each of the lessons uses elements of the 5E model of Engage, Explore, Explain, Elaborate, and Evaluate. These lessons may be downloaded from http://cosmictimes.gsfc.nasa.gov/1929/1929.html

Discovering the Milky Way (grades 9-12)
Students read the original paper written by Henrietta Leavitt in which she compared the apparent brightness to the period of a sample of Cepheid variable stars. By preparing graphs from a sampling of Leavitt's data, students discover the relationship that she observed between the period and luminosity of the variable stars. This lesson is given below.

Just How Far is that Star? (grades 9-12)
In this investigation, students use a "point-source" light, light meters, and graphing software to quantify the reduction in light intensity over distance. After using a best-fit to their data to discover the inverse square rule, students then calculate the distance between the light source and the light meter at random placements. Finally, students extend this principle to model the manner in which distances to Cepheid variable stars are measured.

Cosmic CSI (grades 9-12)
Students learn how the Doppler effect changes our perception of wavelengths and model how astronomers use line spectra to identify elements in stars and the speeds of galaxies.

Determining the Universe (grades 10-12)
Students use a hands-on demonstration to explore and understand how General Relativity explains gravity. Students also develop research topics about Einstein and his theories through a think-pair-share.

Unsung Heroes of Science (grades 7-12)
The students identify and describe unfamiliar scientist "heroes" that contributed to the field of science up to the year 1929. They create a T-square to identify the women scientists of the Harvard College Observatory and use internet resources to give a presentation on one of the these unfamiliar scientific "heroes." This lesson is given below.

Unsung Heroes of Science

Suggested Grade Level(s): All Grade levels from 7-12
Estimated class time: Sections I-III can be done in about 1 class period.
Sections IV - V may take an additional 4-5 class periods.

Summary

Students use resources such as the Internet to identify past scientists who are not well known. They create a T-square to identify the women scientists of the Harvard College Observatory; and they use the Internet to complete a product and give a presentation on one unfamiliar scientific "hero" discovered in their research.

Objectives

- To describe an unknown science "hero" who contributed prior to 1929.

National Science Education Content Standards

NS.5-8.7 & NS.9-12.7 HISTORY AND NATURE OF SCIENCE
- Science as a Human Endeavor
- History of Science and Historical Perspectives

Knowledge Prerequisite

The students should be familiar with famous scientists who have contributed their works to the field. The students should be able to research a topic and report on that topic.

Teacher Background

The teacher should be familiar with the obscure scientists from around the turn of the century. The teacher should be familiar with the women who worked for Edward Charles Pickering at the Harvard College Observatory and their contributions to astronomy.

Materials

- Scientific resources and Internet access (note that the version of this lesson available on-line includes lists of trustworthy websites for research)

Procedure

I. Engagement

Ask students to create a list of famous scientists/astronomers. They can review their Earth and Space Science/Science textbooks for notable figures in physics, biology, and chemistry. Who do they read about? Ask them to share some of these scientists with you.

Use those names and others to mark index cards or post-it notes with the names of 5-10 well-known scientists/astronomers such as Albert Einstein, Edwin Hubble, Isaac Newton, Marie Curie, Harlow Shapley, Charles Darwin, and Thomas Edison. Make a second set of cards or notes with 5-10 less-known scientists/astronomers such as Henrietta Swan Leavitt, Milton Humason, Annie Jump Cannon, Maria Mitchell, and John Goodricke.

II. Exploration

See "Pickering's Harem": http://cfa-www.harvard.edu/~jshaw/pick.html. In groups of 4-5 students, the class briefly researches web sources on the women of Pickering's Harvard College Observatory.

III. Explanation

Each group will complete a T-square on Pickering's lady scientists of the Harvard College Observatory. The students use one piece of paper to create a large T. One side at the top is FACTS LEARNED and on the other side is BIG IDEAS OR CONTRIBUTIONS, as shown in Figure 1 below. Under each column, the students are to fill in the facts and the contributions to set up for their discussion.

Facts Learned	Big Ideas or Contributions

Figure 1: Illustration of the T-square columns

The discussion should be based on the following key ideas:

1. Read and discuss the web pages and pictures out loud with your science class.
2. Discuss the role of the women at the College Harvard Observatory, including how they refer to each woman's role at the observatory (many of the women are referred to as computers).
3. Discuss the role of the women as scientists in society at that time.

IV. Elaboration

"Who's Not in Your Textbook?" – Have students select an "unsung scientific hero" – an scientist who has contributed to astronomy, but who is not well-know today, and who they think deserves more credit. They can use their T-squares as a basis for their project/presentation. Have students use online resources for their research.
Students can use the following list of scientists to choose from or come up with one on their own pending approval from their teacher: Henrietta Swan Leavitt, Annie Jump Cannon, Caroline Herschel, John Goodricke, Milton Humason, Williamina Fleming, Cecilia Payne-Gaposchkin, Mary Somerville, Antonia Maury, Maria Mitchell, etc…

V. Evaluation

Students could create the following: written reports, multimedia presentations using images, video, audio and Powerpoint, podcasts, blogs, or write skits or short stories based on that individual's experience and accomplishments. As part of their presentations, students should address how this person inspired them.

Discovering the Milky Way

Suggested Grade Level(s): 9-12
Estimated class time: one to two class periods

Summary

Students will read the original paper written by Henrietta Leavitt in which she compared the apparent brightness and period of some variable stars called Cepheids. The students will prepare graphs just as she did and compare their data to hers. They will discover that there is a relationship between the period and luminosity of the variable stars she observed and experience for themselves how scientists really collect data.

Objectives

- Students will prepare graphs from numerical data using standard technique.
- Students will compare those graphs with additional logarithmical graphs they prepare from the same data.
- Students will use both sets of graphs to find relationships between the variables.

National Science Education Content Standards

NS.9-12.1 SCIENCE AS INQUIRY
NS.9-12.4 EARTH AND SPACE SCIENCE
- Origin and Evolution of the Universe

Knowledge Prerequisite

Students should be familiar with general terms: Plot, origin, abscissa, ordinate, apparent and absolute magnitude, variable stars (particularly Cepheids and RR Lyrae stars), globular clusters, Small Magellanic Cloud, and the Cepheid period-luminosity relationship

Materials

- a copy of Leavitt's original paper (see online version of lesson)
- standard quarter inch graph paper
- logarithmic graph paper

Teacher Background Notes

Students should not know until later that they are plotting data collected by a "real scientist"

This activity can be done using Excel or some other computer graphing program, however it might be more meaningful for students to plot the points on paper just as Henrietta Leavitt did originally. For younger students, the practice in doing the graphs "by hand" is very valuable.

When students plot the first set of data they should begin to see a trend in the relationship between the magnitude and period variables. If they plot both the maximum and minimum appar-

ent magnitudes separately, they should see the same trend developing. Addition of more data should make them more confident of the trend they see. Using the log 10 of the period will help to straighten and condense the trend line on the graph. Some students will be reluctant to conclude that a firm relationship exists unless all of the data falls on a perfectly straight line. Others will happily accept a conclusion if as few as three points fall in the same general area. Discuss with students that scientists are always faced with this kind of problem. The original data in Leavitt's paper did not take into account that all variable stars do not behave exactly the same way on the Period-Luminosity Relation diagrams. Shapley's calculations of distance using the Cephied variables lead to the discovery of the Milky Way Galaxy, but improvements in technology, measurements and understanding which came later expanded our universe even more.

Procedure

I. Engagement

Since the days of the earliest astronomers, the faint band of light which we now call the Milky Way has been visible in the night sky. However, no one knew what it was. The biggest discoveries in science start with the collection of the smallest bits of information. Then scientists build on the work of their predecessors, refining the information collected earlier until a new picture of our natural word unfolds. Careful observation, painstaking recording, and thoughtful analysis are the foundation of science.

II. Exploration

Suppose that you have been taking photographs of the same region of the night sky over a long period of time and notice that some stars seem to be brighter on some nights than they are on others. What is the term for the brightness of stars as they APPEAR from Earth? (Remember that lower star magnitude numbers represent brighter stars than higher numbers) By comparing the nightly photographs you see that the period from brightest to dimmest can vary from slightly more than one day to as long as 127 days. The Table 1 below shows the information collected for 14 of these variable stars.

While a list of data is useful, sometimes a graph reveals relationships between the bits of information, which may not be obvious when viewed as a simple list. Draw a graph with the apparent brightness on the Y axis. **Because higher numbers represent dimmer stars, your graph should show numbers on the Y axis in reverse numerical order (i.e. 16 at the origin of the graph and 10 at the top).** Show the period of brightest to dimmest in days on the X axis. Use one color to represent the maximum brightness and another to represent the dimmest. Or you may want to make two separate graphs, one for the maximum brightness and another for minimum brightness. **Teacher:** Figure 1 shows a sample of what the plot should look like.

Do your graphs show any trends or patterns? What would make you more confident?

Collecting the information about these stars is very difficult because the stars appear to be very crowded in the regions where they occur. The variable stars are very faint at best and long cam-

era exposures are needed to capture them at all. The number of photographs is very small. However with much care and the fortune of having some clear weather and "good seeing" you collect information about 11 more variable stars. Add the new information from the table below to the graphs you have already begun.

Does the additional information help to confirm or deny a pattern or relationship between apparent brightness and period? Sometimes a mathematical operation can help to clarify the collected raw data. Redraw your graph using the log of the respective periods on the X axis instead of the actual number of days. Find the log (base 10) of each period using your calculator. **Teacher:** Instead of taking the log of the periods, your students could plot the semi-log paper with the log axis as the x-axis. Figure 2 shows a sample of the second, log-based plot.

III. Explanation

What effect did using Logs have on the shape of your graphs? Do you see a pattern emerging from the data? What else do you need to know before you can draw any conclusions? Hint: What factors can affect the brightness of a star? Remember that you are viewing the Apparent Magnitudes. Find a definition for the term Absolute Magnitude. Do you know the absolute magnitude for the stars on your graphs? If you knew that all of the stars on both tables were in the same group and approximately the same distance from Earth, could you now draw a conclusion about the relationship between maximum brightness of a variable star and the length of its period? How confident would you be about the validity of your conclusion? How could this pattern of period- apparent brightness of variable stars be used? Your teacher will show you a research paper prepared by a Harvard University researcher. Compare your graphs and conclusions to hers. Would you have reached the same conclusion she did?

IV. Elaboration

Read the included document about some interesting history to see how this data laid the groundwork for additional new knowledge.

For further reading about this topic or for a sample sheet of semi-log graph paper, please check out the on-line version of this lesson available here: http://cosmictimes.gsfc.nasa.gov/1929/lessons/lessons.html

Table 1: First Data Set: Data for 14 variable stars

Star	Max.	Min	Period
A	14.8	16.1	1.25
B	14.8	16.4	1.76
C	15.1	16.3	1.88
D	14.6	16.1	4.29
E	14.3	15.3	4.54
F	14.3	15.5	4.99
G	14.4	15.4	5.31
H	14.3	15.2	5.32
I	14.1	14.8	6.65
J	13.9	15.2	8.39
K	13.6	14.7	10.34
L	13.4	14.6	16.75
M	12.2	14.1	31.94
N	11.2	12.1	127

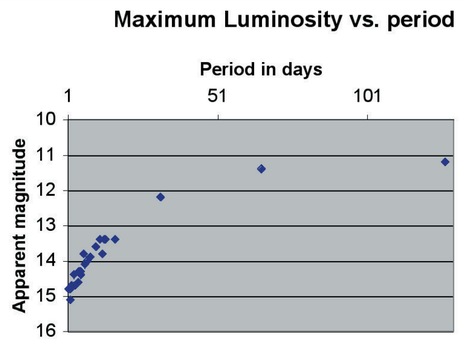

Figure 1: Plot of data in Tables 1 and 2

Table 2: Second Data Set - Data for an additional 11 variable stars

Star	Max	Min	Period
O	14.8	16.4	1.66
P	14.7	15.6	2.17
Q	14.4	15.7	2.91
R	14.7	15.9	3.5
S	13.8	14.8	6.29
T	14	14.8	7.48
U	13.4	14.6	11.64
V	13.8	14.8	12.41
W	13.4	14.4	13.08
X	13.4	14.3	13.47
Y	11.4	12.8	65.8

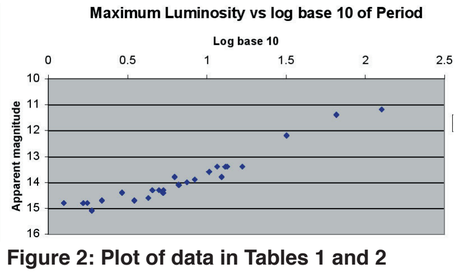

Figure 2: Plot of data in Tables 1 and 2